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THE FUNGUS DISEASES OF THE TEA LEAF

BY

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AND

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(Continued from 1921, Part IV, Page 213).

Blister Blight—*Exobasidium vexans*, Mass.

In the course of the investigations careful enquiries were carried out on every garden in the Darjeeling district and the following conclusions were made.

Jat of tea: It was found that all jats of tea were attacked similarly. The only distinction that can be made is that in certain cases the dark-leafed jats of tea appeared to be less susceptible. Not only were all jats susceptible but no individual bushes were found to be immune.

Class and condition of soil did not make any appreciable difference to susceptibility.

Climate was found to be the most important factor in the distribution of the disease. Elevation alone was only of importance in so far as it influenced the temperature and humidity. The optimum temperature is somewhere in the neighbourhood of 60°F and the damper the atmosphere the better for the blight. As a rule the best conditions for the blight are when a few days of good growing weather are succeeded by dull cool weather. The good growing weather provides an ample supply of suitable leaf and the succeeding dull damp weather gives optimum conditions for the distribution of the spores of the blight. Shade, particularly damp shade, favours the disease and bright sunshine is the best cure known.

Cultural conditions are only important in so far as they regulate the condition of the leaf. The more succulent the leaf, the more liable it is to attack. Manures tending to produce rank growth, *e.g.*, those rich in nitrogen, tend to increase the susceptibility to attack. One of the most important factors governing the condition of the leaf is the pruning of the bush. The heavier the pruning the more succulent the leaf. Pruning is also important from the following point of view. Badly pruned and unpruned bushes have a lot of twiggy wood inside the frame and young shoots are often present on this wood in the cold weather. The blister frequently may be found on those shoots throughout the year. They therefore act as harbouring places for the disease. Plucking is naturally of great importance as the only leaf blister can attack, is the succulent leaf.

The Presence of Exobasidium in the Jungle.

In the course of the investigations on blister blight in Darjeeling a prolonged search was made for the disease on other plants in the jungle in the neighbourhood of the tea gardens. Only one plant was found with a disease resembling blister blight. This plant was *Symplocos theæfolia*, Kherani. A careful investigation of the fungus on it led to the conclusion that although it was an *Exobasidium* it was probably a different species from that found on tea. It was then concluded that the tea disease fungus was not present in the jungle. Later on, however, an outbreak of blister occurred in the Mangaldai district on a garden adjoining the hills. There seemed to be nothing to account for the sudden appearance of the disease as the garden in question was well isolated from other tea. The gardens in North Lakhimpur and a few in the Dooars were also affected similarly. A study of the climatic conditions of these gardens revealed nothing strikingly different from the other gardens in the districts in which they were situated. Their geographical situation was then studied and it was found that deep valleys cut off most of the gardens in the districts which are so far immune from direct communication with the higher ranges of the Himalayas while the gardens on which the blister had appeared were not so isolated. It seemed

EXOBASIDIUM ON SYMPLOCOS THEÆFOLIA (KHERANI).

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possible that the disease had some connection with the higher ranges of the Himalayas. All the gardens in Tezpur, Bishnath and Behali have never had blister, while those near the hills in Mangaldai and North Lakhimpur get it. In Darjeeling this opinion was strengthened by the knowledge that the disease started at the top of the Rungbong valley in 1909 and did not reach the Teesta valley gardens until two years later. The disease was found at Munsong on a few acres of tea planted in the cinchona in 1907 or 1908. In 1908 it was found on two gardens in the hills near the Dooars and another in Bhutan. Rungbong valley is in direct connection with the higher ranges while the Teesta valley is cut off from them by the valleys of the Teesta and Rungeet. An explanation of this apparent connection with the higher ranges of the Himalayas was then sought. From native rumour it was learned that the *Rhododendron* forests were attacked by a disease similar in appearance to blister blight. It was some time before an opportunity could be made to further investigate this, but in 1919 the Mycologist visited the *Rhododendron* forests in the neighbourhood of the Jelap La Pass. He timed his visit so that he would arrive there at the time when blister would be likely to appear. As the season was exceptionally dry he delayed his departure until he got news that *Exobasidium* was actually prevalent on some of the jungle trees. He then set out accompanied by two Lepcha botanical collectors from the Lloyd Botanic Garden for the Jelap La Pass into Tibet. He reached Kalimpong the first day *viâ* Rungeet valley and Melli bridge. He went on next day to Pedong where he stayed for some days while the jungle was searched for the blister. Here he had the pleasure of meeting Mr. Green of the Munsong Cinchona Plantation, who gave him a list of the trees on which he had observed disease resembling blister blight. The Lepchas had meanwhile obtained *Exobasidium* on Ungiri (*Pieris ovalifolia*) Kherani (*Symplocos theæfolia*) and another shrub which they also called Kherani. Successful cultures were made of these and microscopic slides, drawings and photographs prepared. A move was then made to Sedonchen, spending one night at Ari *en route*. At Sedonchen the Mycologist camped for some days while the

Lepchas searched the jungle round Gnatong (12,300 ft.) and the Jelap La Pass (14,300 ft). The road below Sedonchen climbs up a magnificent gorge, passing successively all classes of vegetation, from tropical to Alpine forests. It is very steep, rising over 10,000 ft. in 20 miles. The *Rhododendron* forest begins about 9,000 ft. above sea-level and continues to about 13,000 ft. It was in this belt that the *Exobasidium* was most prevalent. The weather was very wet and the mountains were enveloped in thick mist, just the thing for the blister blight and the epidemic of disease was just at the right stage when the Mycologist observed it. All species of *Rhododendron* seemed to be attacked and the yellowish or pinkish blisters were almost as noticeable a feature of the landscape as flowers. Cultures, slides, photographs and drawings were obtained of *Exobasidium* on five species. The natives stated that this disease had only appeared in recent times, *i. e.*, within their recollection ; but this information may not be reliable. When no further specimens were forthcoming the Mycologist returned to Darjeeling *viâ* Pedong, Kalimpong and Rungli Rungliot. It was found that the shapes and si^{z}es of the *Exobasidium* spores varied very considerably not only on the different species of *Rhododendron* but also on the same species. Some of the blisters examined had spores of size and shape similar to those found on tea. Unfortunately it was not possible to carry out inoculation experiments on tea as the cultures did not survive the journey to Assam and so far it has been impossible to spare the time to make another trip to collect fresh material. Special precautions such as the provision of cool incubators, ice boxes, etc., are necessary to ensure the satisfactory growth of this fungus on artificial media under the climatic conditions of Assam in the rainy season. The blister blight of tea very rarely survives the journey from Darjeeling to Assam. It is obvious that the disease was not introduced into Darjeeling in peoples' clothes or in any other accidental way of a similar nature from Assam. It is extremely unlikely that the disease was carried in tea seed as Assam tea seed from infected gardens has been exported to many places for many years without any outbreak of blister blight following. It seems much more probable, in view of the infor-

Exobasidium sp. on jungle trees growing in the *Rhododendron* forests of the Himalayas near the Jalap La pass.

mation given above, that the disease has spread from somewhere north of China through the *Rhododendron* forests of the Himalayas and that it reached Darjeeling in this manner. During a portion of his long leave the Mycologist paid a visit to one of the higher mountain ranges in the Naga Hills and found the disease in the *Rhododendrons* there also. The plate shows the appearance of *Exobasidium* on various species of *Rhododendron* and allied plants. Until further work has been carried out on these species of *Exobasidium* it is impossible to say which, if any, is identical with that found on tea. They all vary so much individually that it is possible they are all the same species.

These *Rhododendron* forests are a long way from the present tea gardens and it may well be asked how the fungus covers the intervening distance. A study of the temperature records in relation to outbreaks of the disease shows in many cases that a sudden fall in temperature occurred ten days to a fortnight before the disease appeared. In Darjeeling and other places close to the Himalayas a sudden fall in temperature is generally due to a wind from the mountains. In cases where there is no deep, hot valley in between the spores of the blight could easily be carried the required distance without injury. The intervention of a deep valley would alter the humidity and temperature of the wind besides possibly changing its course. As it takes ten days to a fortnight for the disease to develop blisters after infection it is possible that infection took place about the time the spores causing the outbreak were borne on the wind which caused the lowering in temperature.

Treatment.

Manuring: Some experiments were made with manurial applications and salt and potassium chloride were tried with a view to checking the growth of young leaf temporarily. They did check the growth and reduce the intensity of blight attack in consequence. It was hoped that this temporary check would enable the spraying or other treatment to get ahead of the blight. It was not altogether satisfactory as the climatic conditions are such that the effect both of the manure and the spraying only persisted a very short time.

Spraying : A great many experiments were made to determine the best spray fluid. It was found that spraying alone is only a palliative whatever solution is employed. The climatic condition and the manner in which tea grows make it impossible to cure a disease like blister blight by spraying alone. The spray fluids experimented with may be divided into three groups. Firstly, those calculated to stimulate the plant so that the leaf will grow more rapidly than the fungus ; secondly, those intended to check the growth of the leaf and cause the succulent leaves to harden rapidly thus making them less liable to attack, and thirdly, those whose action is fungicidal.

Spraying the bushes with weak solutions of nitrate of soda was tried with the first object, but it was found that although the growth was to some extent stimulated the bushes were rendered more liable to attacks of such diseases as brown and copper blight. This method of treatement was therefore abandoned.

Salt and potassiam chloride solutions were tried for the purpose of hardening the leaves rapidly. They succeeded in their object but reduced the crop considerably. Their use, except in special cases, is not therefore recommended. The most satisfactory fluids were those which had a direct fungicidal action. Very many experiments were carried out with these. Bordeaux mixture in various forms and concentrations, Burgundy mixture and lime sulphur solutions were tried. It was found that for practical work solutions requiring special care in their preparation and application were undesirable. Burgundy mixture is easier to prepare than Bordeaux mixture, and although Bordeaux mixture of similar concentration is a better fungicide than Burgundy mixture the latter is preferable for practical use. Unfortunately both Bordeaux and Burgundy mixtures form precipitates and in their application it is necessary to keep them well stirred. This is seldom done properly on tea gardens and for this reason we have been led to recommend lime sulphur solution as the best all round spray fluid for practical use. The preparation and storage of the concentrated solution requires a little care, but it can be done at the tea house under European supervision, but there is little possibility of mistakes occurring in the field where supervision is necessarily more difficult.

Pruning and Plucking: On gardens where the tea is thoroughly well pruned and where there is no abandoned tea on which the disease may pass unobserved it has frequently been found possible to eradicate the disease altogether from the garden by the careful removal of all blisters in the cold weather. This of course is quite out of the question in the case of Darjeeling gardens as the distances between gardens are not great enough to prevent re-infection from neigbours, but careful pruning will in any case facilitate treatment of the disease. It is of course necessary to prune heavily at times, but whenever heavy pruning is carried out it should be done as early in the cold weather as possible so that good growth will be obtained before the blister blight season arrives. If this precaution is neglected it is probable that the young shoot will be killed right down to the heavy wood and some of the bushes may die right out. In any case it is desirable that heavy pruned tea be protected by frequent applications of spray fluid until satisfactory growth has been assured. None of the systems of plucking ordinarily carried out were found to influence the blight noticeably. Various planters in Darjeeling tried hard plucking with the idea that by removing all the succulent leaf the blister would die out for lack of food. This idea was very sound in theory but was impossible in practice as labour was insufficient to carry it out over the whole area. In consequence the heavy plucked blocks were re-infected from the surrounding tea and their last condition was worse than before. Under certain circumstances the removal of all succulent leaf is a very satisfactory method of dealing with the disease. For instance in the cold weather the careful removal of all succulent leaf from unpruned and light pruned tea and the spraying of the rest with fungicidal solutions does eradicate the disease and in the case of isolated gardens this method has been proved effective repeatedly.

The development of the disease in the leaf takes some time and when the leaf grows more quickly than the disease it is possible to save a lot of tea by plucking it before the disease has had time to produce blisters. Unfortunately under Darjeeling conditions the blister generally grows more quickly than the leaf and in

consequence the leaf is badly injured before it is ready for plucking. In Assam the rapid growth of the leaf prevents the disease doing much damage except on young and cut-back tea. In the growing season, however, the removal of all succulent leaf is not only impossible but undesirable when the attack is general. If there is no possibility of preventing further infection the removal of all succulent leaf would possibly cause more serious injury to the bush than the disease as the new leaf may be infected as soon as it appears and the bush may suffer by the abnormal restrictions of its leaf surface. If the leaves usually left in the bush are not removed although they may have blisters on them the uninjured portions will still continue their functions and the later flushes will lose little in vigour. On the other hand in the case of a small outbreak of the disease it is possible to prevent further spread and ultimately to eradicate the disease by close plucking the area in which it has appeared, taking precautions to prevent it from spreading to other areas by various methods to be discussed later.

Co-operative treatment: In the case of isolated gardens blister blight is not a difficult disease to eradicate, but in a district like Darjeeling where the gardens are so situated that isolation is out of the question the problem is very difficult. It is extremely unlikely that disease will ever be eradicated and it is quite impossible to even check a severe attack unless gardens act in strict co-operation. In 1913 one of the writers proposed a co-operative scheme for dealing with this disease and the scheme was favourably received by the planters. It was decided that it be tried on a small scale in a more less isolated portion of the district. The outbreak of war and the subsequent slump prevented the attempt being made. The scheme is described at length in *Quarterly Journal*, 1916, Part IV, pp. 142–153.

Summary of Recommendations.

The treatment of blister blight may be summarised as follows:—

1. The careful removal of all blistered leaves in the cold weather.

2. Keeping a careful watch for all outbreaks throughout the season.

3. Immediate isolation of infected areas. Only special coolies should be allowed to go into them and these coolies should change their clothes immediately afterwards.

4. The immediate removal of all blistered leaves and also the removal of all leaves liable to attack from the infected bushes and their neighbours. The leaves should be buried on the spot.

5. Spraying the infected areas with a fungicidal solution such as Lime sulphur solution, Bordeaux or Burgundy mixtures, immediately after removing the leaves.

6. Repeating the spraying of infected areas when the new leaves are appearing.

7. Heavy pruning should be carried out as early as possible.

8. All heavy pruned or young tea should be protected by repeated applications of spray fluid.

FACTORS AFFECTING THE QUALITY OF TEA

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The Notes on Tea Manufacture published in *Quarterly Journal* 1921, Part II, were received with so unexpectedly great an interest, and led to so many questions dealing with the subject of quality generally and particularly on the purely scientific side, that it is thought well to add more detailed information to the admittedly scrappy notes given in partial explanation of the practical manufacturing operations advised.

Part I.

Constituents of the Tea Leaf: In tea leaf the following are the more important substances found:—caffeine, essential oil, albuminoid substances, the ash constituents (lime, potash, phosphoric acid, silica, etc.), gummy substances and tannin.

As before stated, *caffeine* although responsible for the refreshing properties of tea is a colourless, odourless and practically tasteless substance and would not therefore be expected to influence the market value of tea.

The *essential oil* is prepared by distilling tea with steam, and dissolving the oil with ether from the water with which it distils over. The essential oil is thus obtained in very small quantity. Bamber found about 3 parts in 10,000 parts tea, and describes it as forming colourless, highly refracting, irregular-shaped drops. Von Romburgh found only 6 parts in 100,000. The quantity obtainable being so small the essential oil has been very little investigated, It has been shown to contain acetone, methyl alcohol, and methyl salicylate which are factors in producing the aroma, but the substance responsible for the characteristic odour of tea has not been discovered. Green leaf possesses none even when crushed,

(although it contains some volatile oil), but properly withered leaf always has a pleasant smell resembling that of made tea, while the full aroma only appears during firing. The percentage of volatile oil increases after fermentation, and decreases during firing by evaporation.

The *albuminoids*, being extractable by boiling water only in small quantity, are of little interest. They do, however, probably render some of the tannin insoluble during the fermentation process and therefore have an indirect influence on quality.

In Japan it has been found that amino-acids have an influence on the quality of green tea. The quantity of these compounds in the leaf is increased by manuring with nitrogenous manures and flavour is also increased. With black teas in India nitrogenous manuring tends rather to decrease than to increase quality probably by lowering the tannin content (marked pungency is not esteemed in green tea) and it may therefore be assumed that these amino-acids have little influence on the flavour of black teas.

The *ash constituents* can have little or no direct influence on quality, but Mann gives a few analyses showing that teas of good quality contain higher proportions of phosphoric acid and potash than poor teas.

Gummy substances (pectin, pectoses, etc.) occur in considerable quantity, and dissolve to a great extent in boiling water. Bamber suggests that they may affect quality by increasing the "thickness" of the liquor. On cooling they form substances of a gelatinous consistency, which Bamber suggested might form part of the solid which is precipitated out of solution when good teas "cream down." "Creaming down," however, is probably due to certain properties of tannin and caffeine which will be mentioned later.

Tannin has a marked astringent taste and is present in considerable quantity in the infusion made with boiling water. It therefore greatly influences the taste of the liquor. Its fermentation products are strongly coloured and therefore influence the colour of the liquors. At least one of the fermentation products has an agreeable sweet taste.

It would appear, then, that the quantity of tannin present should be an appreciable factor in influencing quality as measured by market price.

Influence of Tannin on quality:—Hooper and Mann have separately published a certain number of analyses showing some connection between tannin content and market price.

Mann quotes the following figures :—

	Cachar Pekoe.	Duars Pekoe.	Duars Pekoe Souchong.	Assam Pekoe.	Assam Orange Pekoe.
Value in annas ...	4/2	4/2	3/8	5/2	7/6
Total matter dissolved ...	28·38	26·29	23·69	29·38	31 58
Tannin %	7·56	7·29	6·48	8·23	10·98

These figures were obtained after five minutes' extraction at the boiling point of water.

In 1914 and 1915 a large number of analyses were made by the writers, but were not published partly because the results were not very definite, and partly because the chemist chiefly concerned left the Department for war service before the work was completed.

If only to save further effort in the same direction the results are now summarised as shortly as possible.

In addition to total tannin* and caffeine, the total soluble solids, and "combined" tannin and caffeine, were estimated.

A strong infusion of tea deposits on cooling a dark-coloured precipitate; the tea is said to "cream down." A worker

* Tannin was estimated by titration with permanganate of the extract (to which indigo carmine had been added), before and after precipitation of the tannin by gelatine. The factor used for calculation was 1 cc. N. K MnO_4 = ·0416 grams tannin. The method therefore estimates all the soluble oxidisable matter which precipitates gelatine, and includes all substances which possess tanning properties. Total solids were determined by evaporating a part of the extract to dryness. In all cases results are calculated as percentages of the dry tea.

(unnamed) in the "Lancet" laboratory showed that this precipitate contained caffeine and tannin, roughly in proportion (by weight) of 3 parts tannin to 1 part caffeine. He suggested that a compound of tannin with caffeine had properties different from that of a mere mixture of tannin with caffeine, that the supposed harmful physiological effects of free tannin and free caffeine were reduced by the combination of the two to form a compound, and that this compound possessed an agreeable flavour superior to the coarse pungency of free tannin. The "Lancet" worker published a number of analyses of good and bad teas showing that the ratio of tannin to caffeine in good teas was roughly 3 : 1, while in teas of poorer quality there was an excess of one or the other.

The rough proportion of 3 parts tannin to 1 part caffeine in the "creaming down" precipitate was confirmed in the Tocklai laboratory. This "cream" was found to be more completely precipitated when salted out by saturating tea extracts with ammonium sulphate, and a precipitate of similar composition was obtained even from weak tea infusions by saturating the liquid with ammonium sulphate. In the following analyses "combined caffeine" was estimated by saturating the infusion with ammonium sulphate, and estimating the caffeine in the precipitate. The figures given under "combined tannin" are approximations obtained by multiplying the percentage of "combined caffeine" by 3.

Extracts made by the methods used by tea tasters, were found to vary very considerably in composition and to such an extent that they could not be used for supplying analytical data. The extracts analysed were prepared by boiling 5 grams of tea with 400 cubic centimetres of water for half an hour under a reflux condenser, cooling, and making up the volume to 500 ccs. By this method extracts of constant composition were obtained.

The following table (Table I) shows the results obtained on samples of B. O. P. The prices given are with few exceptions Calcutta valuations (1914) at about the same time. In a few instances selling price only could be obtained.

TABLE

Broken Orange

Day Book No.	Number of samples in order of value.	Valuation.			Total tannin.	Total solids.	Percentage tannin in total soilds.	Total caffeine.	Combined caffeine.	Combined tannin.
		Rs	As.	P.						
39	1	3	0	0	27·3	47·3	57·7	7·36	3·49	10·5
57	2	0	13	6	20·1	42·8	47·0	4·65	3·77	11·3
60	3	0	12	6	18·1	44·0	41·1	.....	...	.....
44	4	0	12	6	16·1	43 6	37·4	4·87	2·77	8·3
71	5	0	12	0	18·5	43·9	42·1	6·63	2·06	6·2
12	6	0	11	6	15·4	42·7	36·1	4·8	2·0	6·0
36	7	0	11	0	21·2	42·7	49·9	5·04	4·05	12·2
27	8	0	10	9	16 3	43·6	37·4	4·52	3·14	9 4
59	9	0	10	6	19·4	43·7	44·4	.....	.....	.....
29	10	0	10	3	19·3	43·1	44·8	.....	.....	.....
74	11	0	10	0	17·5	43·9	40·0	4·31	3·02	9·1
6	12	0	10	0	13·7	41·3	33·2	4·44	1·73	5·2
31	13	0	9	9	17·5	42·4	41·2	4 07	3·32	10·0
25	14	0	9	6	18·3	43·6	42·0	4·96	3·36	10·1
35	15	0	9	4½	18·2	44·9	40·5	4·23	2·95	8·9
46	16	0	9	3	16 1	43·0	37·7	3·62	3·31	9·9
77	17	0	9	0	14·9	43·9	33·9	4·44	4·05	12 1
18	18	0	9	0	18·8	41·6	45·2	4 54	2·70	8·1
20	19	0	8	9	18·5	43·2	42·8	.....	.....	.....
21	20	0	8	9	17·5	42·2	41·5	4·53	2·55	7 6
55	21	0	8	7½	18·5	43·2	42·8	5·72	3·10	9·2
16	22	0	8	4½	18·5	41·3	44·8	4·40	2·34	7·0
75	23	0	8	3	13·5	41·6	32·5	3·48	2·80	8·4
7	24	0	8	3	14·4	40·6	35·5	4·18	2·63	7·9
24	25	0	8	3	18·0	42·7	42·1	5·60	2·57	7·7
40	26	0	7	10½	15·9	40·2	39·5	4·68	.....	.....
13	27	0	7	10½	18·5	41·3	44·8	3·09	2·70	8·1
32	28	0	7	9	14·0	41·1	34·1	3·71	2·80	8·4
69	29	0	7	7	13·7	40·4	33·9	4·93	3·90	11·7

I.

Pekoes.

Solids not caffeine or tannin by difference.	Free tannin.	Free caffeine.	Remarks and Tasters' Report.
12·6	16·8	3·87	Fine pungent liquor. Cup colour good. Infusions bright. Dry leaf good make and very good bright tip.
18·0	8·8	0·88	....
.....	.....	.....	....
22·0	7·8	2·10	Fair liquor lacking in briskness. cup colour fairly good. Infusions bright. Dry leaf good make and twist some bright tip.
19·8	12·3	4·57	....
22·5	9·0	2·8	Fairly good infused leaf. Fair quality. Brisk, fairly strong and coloury, little point. Well made leaf. Even fair tip.
16·5	9·0	1·0	....
22·8	8·9	1·4	Liquors too thin but fair strength. A little flavour but wanting in quality. Infusions dull and green. Dry leaf well made. Fair amount bright tip.
.....	.....	.....	B. O. P. Liquor a little strong and full. Infusions fair.
....	.....	.....	....
22·1	8·4	1·29	Useful B. O. P. with fair tip.
23·2	8·5	2·71	Good size, little mixed with fannings few tips, wanting in briskness fair colour and strength liquors barely equal to usual standard.
20·8	7·5	0·75	....
20 3	8·2	1·60	Liquors fair colour and strength. Infusions fairly bright. Dry leaf useful make.
22·5	9·3	1·3	Blackish leaf, colour fair, Brisk liquor. Infused leaf a shade dark.
23·3	6·2	0·31	....
24·6	2·8	0·39	....
18·3	10·7	1·84	Nice liquors with a little flavour. Useful colour strength. Infusions fairly bright. Dry leaf useful.
.....	.....	.....	Leaf black brokén pekoe fair tip clean brisk liquor.
20·2	9·9	1·98	Plain liquor. Useful colour and strength. Infusions not very bright. Dry leaf has fair size and make.
19·0	9·2	2·62	Clean plain liquor. Cup colour fairly good. Infusions a little bright. Dry leaf good make.
18·4	11·5	2·06	Liquor fair colour and strength. Infusions fairly bright, some green showing up. Dry leaf a little mixed.
24·6	5·1	0·68	....
22·0	6·5	1·55	....
19·1	10·3	3·1	Clean but rather light liquor. Cup colour fairly good. Infusions show up a little green. Dry leaf has good make.
19·6	.....	.....	....
19 7	10·4	1·39	Liquors fairly bright with useful colour and strength. Infusions rather dull mixed. Dry leaf useful size and make, B. O. P. very flat and Flakey.
23·4	5·6	0·9	....
21·8	2·0	1·03	....

In the case of the No. 5 tea selling price on the London market only was obtained, and for comparison with the others its value has been put down as 2 annas less than the number of pence per lb. paid in London.

Tasters' reports are given in cases where they were obtainable.

It will be seen that the percentage of combined caffeine present has no apparent relation to the market price, neither has the percentage of free tannin.

The total caffeine, although the extreme variation is between 3·09% (near the bottom of the table) and 7·36% (at the top of the table), is in only a few instances greatly different from between 4 and 4½ per cent., and such variation as exists is quite irregular. Total caffeine, then, cannot be correlated with price.

The total solids vary only between 40·2 and 47·3, and the percentage is rarely far from 43, yet high figures are fairly consistently found at the top of the table, and low figures at the bottom.

The figures for total tannin vary between 13·7% and 27·3% and the correlation with price is not to close as in the case of the total solids, yet here too, high figures appear at the top of the list, and low figures at the bottom. Tannin is assumed to give liqours the quality known as "briskness" and "pungency." Since this is not the only factor affecting the value, this one factor cannot be expected to show a very strict correspondence with price.

Mere appearance, including the colour of the dry tea and presence of tip, has a great value. Neither are the fermentation products of tannin, which affect the colour and taste of the liquors, estimated by the method adopted.

Averaging over ranges of price the following figures are obtained :—

Broken Orange Pekoe.

Valuation.	Total tannin.	Total solids.
11 annas and above ...	18·1	43·8
10 ,, ,, ,, ...	17·7	43·1
9 ,, ,, ,, ...	17·3	43·2
8 ,, ,, ,, ...	17·0	42·2
7 ,, ,, ,, ...	15·3	40·7

While the highest and lowest priced stand out as comparatively high and low respectively in tannin, there is little average variation between 8 and 10 annas.

In total solids again the highest and lowest show up, and there is a remarkable regularity in teas valued between 9 and 11 annas.

It may be said therefore that comparisons of total tannin and total solids will at least distinguish between very good teas and very bad ones although teas of approximately the same class cannot be placed among themselves.

On teas other than B. O. P. the following averages were obtained after analysis of 40 samples, mainly Pekoe-Souchong :—

Valuation.	Total tannin.	Total solids.
9 annas and above ...	15·7	41·1
8 „ „ „ ...	14·8	40·6
7 „ „ „ ...	13·8	39·7
6·6 „ „ „ ...	14·2	39·6

The low average figures compared to those from B. O. P. are noticeable. This however is frequently accounted for by the fact that many of them were not broken teas, while even the broken teas are much coarser than the B. O. P.'s

Being less finely divided, these teas will not give up so much of their soluble matter to boiling water, and therefore give liquors of less "strength," which, in general, seems to be the quality measured by estimation of total solids and tannin. That liquors must possess quality other than strength so measured, is shown by the fact that for example B. O. P.'s averaging 15·3% tannin and 40·7% total solids are valued at only 7 annas, while less broken teas averaging 14·8% tannin and 40·6% total solids are valued at 8 annas. This was in 1914 : whether the less strong liquors would be valued so highly on the present market, is doubtful. Our assumption, then, is that the total soluble solids and tannin give a rough measure of "strength," while the total tannin alone gives a still rougher measure of "briskness" or "pungency."

It is interesting to see how far these assumptions are borne out by the tasters' reports shown in table I.

The No. 1 tea with the exceptionally high tannin content is noticed for its "fine pungent liquor." "Strength" is not noticed. The total solids are only high on account of the tannin present. The solids other than tannin are lower than the average of this class of tea. The No. 4 sample is noticed as "lacking in briskness," and its tannin content is noticeably low for teas of that value. Both Nos. 6 and 12 samples (from the same garden) are comparatively low in tannin. No. 6 is noted as "brisk," which is not in accordance with expectation. This invoice, however, is notably higher in tannin than the other invoice which is noted as "wanting in briskness." The briskness of the No. 6 is possibly only comparative, since all the teas analysed from this garden are below the average in tannin and total solids and presumably get their price for qualities other than strength. They frequently show flavour above the average of the teas analysed, from which teas from districts giving much flavour were excluded in order to avoid interference from the flavour factor as far as possible.

The No. 7 sample possesses high tannin, and although briskness is not alluded to, "strength" is. The green infusions infer inproper fermentation, high tannin being retained at the expense of the necessary fermentation products of tannin.

The No. 9 sample shows high tannin and total solids and is noted as strong and full. Briskness is not mentioned.

No. 14 also analyses well in tannin and total solids. The liquors are only referred to as being of fair colour and strength.

No. 15 is noticed for its brisk liquor and contains tannin above the average for its price.

No. 18 of high tannin content is only noticed for useful strength but No. 19 of about the same tannin content is noted as "brisk."

The high tannin of No. 21 again escapes notice, while that of No. 22 is noted as "strength."

No. 25 only retains a high tannin content because not well fermented. The liquors are light ; and the infusions green because insufficient tannin has been changed to colouring substances during manufacture.

No. 27 is notably high for its price both in tannin and total solids. The taster notices its strength. The low valuation is apparently on account of lack of other qualities. The dull and mixed infusions would lead one to believe that the manufacture had gone wrong in directions that will be briefly alluded to later.

On the whole our assumption as to the effect of total tannin and total solids seems justified, although there are obviously other factors determining quality as measured by market value.

The substances produced by the fermentation of tannin are not estimated by the method used for the determination of "total tannin."

The nature of these substances and their probable influence on quality is indicated by the following brief account of the chemistry of tea tannin. The most complete account yet published is that of Deuss,* from which most of the facts given below are taken. Deuss prepared pure tannin both from made tea, and, more easily, from green leaf. He found it a white powder, which does not crystallize. When dissolved in water, the solution turns brown and on standing in air, becomes cloudy. This brown precipitate is presumably produced by oxidation of the tannin by oxygen from the air. This presumption is confirmed by the fact that when the cloudy brown liquid is shaken with dilute acetic acid and zinc powder (which has the power of absorbing oxygen), the brown colour disappears and a clear uncoloured solution is obtained.

From this solution pure tannin may be obtained by shaking with ethyl acetate which dissolves the tannin out of the water. This brown compound obtained by the oxidation of tannin is called "tannin brown," and is undoubtedly the substance mainly responsible for the brown colour of tea infusions.

* Medeelingen van the Proefstation voor Thee No. XXVII.

When tea tannin is boiled with dilute sulphuric acid for 6 hours, the solution becomes cloudy, and a red substance separates out.

This red substance is called "tannin red."

Similar formation of "reds" is a property of a certain class of tannins, among which are the oak-tannins, but not of all tannins. The formation of "reds" therefore places tea-tannin among this class.

"Tannin red" cannot be changed back to colourless tannin by zinc powder, and is therefore concluded not to be formed by simple addition of oxygen to tannin, but the change involves the splitting off of water from the tannin molecule.

"Tannin red" is present in quantity in infusion from made tea but is not present in infusion from fresh leaf. It is therefore produced during manufacture.

It has a sweetish flavour resembling cinnamon, and its presence therefore influences the flavour of tea. It is soluble in solutions containing tannin, and its presence accounts for the coppery tinge in infusions of black tea, for the colour of infused leaf, and of fermented leaf before firing.

It is much more soluble in hot solutions than in cold. The "creaming down" of a tea infusion is considered by Deuse to be largely the separating out of tannin red as the tea cools. The "cream," however, has been shown also to contain tannin and caffeine as before mentioned. "Creaming down" is therefore a more complicated phenomenon than a mere separation of "tannin red," although this may be concerned.

This tannin red is a most important constituent of fermented teas. A "copper colour," the "colour of a new penny," is always aimed at as the ideal in fermented leaf and infused leaf from made tea, and it appears highly probable that this tannin red, which appears only after fermentation, may be responsible for it.

The "tannin brown" apparently is the cause of the appearance of the "colour of an old penny" in over-fermented or otherwise wrongly fermented tea.

In the days of hand rolling, the rolled leaf was left in fairly tightly rolled balls to ferment, and planters who can remember those days are of opinion that this treatment produced a much better copper-colour than the present method of thin spreading of loose leaf.

The leaf was left in balls in order to fix the "twist" which in those days had a great influence on the price obtained. On hot, dry days it was noticed (see Tea Encyclopædia) that the outside of the ball became dark and discoloured, although the inside retained the desired colour.

The change to loose spreading apparently came in as "good twist" became less esteemed, and greater evenness of colouration was desired.

In the interior of the ball, the oxygen supply must be very limited, yet the desired colour was obtained.

It appears possible that what is desired in fermented teas is as much as possible of "tannin red," with only a minimum of "tannin brown."

This may possibly be obtained by limiting the supply of air during fermentation, but it is essential also that the fermenting leaf shall not become unduly dry. Mann's recommendation to hang wet cloths in the fermenting room receives a new explanation, both in preventing evaporation and in preventing draughts, or streams of air carrying fresh oxygen.

Greenness of the fermented teaf, and of the infused leaf, is caused by failure of the above indicated reactions to go on ; either simply because fermentation has not been allowed to proceed far enough, or when the greenness is patchy, because that part of the leaf has escaped the rolling, so that the cells are not so reduced in vitality as to permit the necessary reactions to proceed. Patchy greenness may in some cases also be ascribed to uneven withering, whereby parts of some leaves escape the loss of vitality due to drying.

The action of enzymes undoubtedly present in fermenting leaf has not been dealt with in this article. The subject is under

investigation at Tocklai, and, no doubt in other places, but it is not desirable to publish anything yet.

It may be noted that the reactions going on in fermenting tea will go on in the laboratory without the intervention of any enzyme. The function of the enzyme in manufacture is probably that of a catalyst. A catalyst is a substance which will by its presence increase the rate of a reaction, although itself undergoing no change.

Part II.

It has been shown that there is only a very rough correspondence between quantity of tannin present in made tea and the price.

The evidence, however, points to the fact that it is largely because the method used estimates unfermented tannin only, and not the substances produced from it during manufacture. The tannin present in fresh leaf, however, being the source of its fermentation products, should have a more direct influence on the quality of the tea.

This point is very difficult to prove directly. It is difficult to obtain samples of unchanged green leaf from any distance ; and it is still more difficult to obtain representative samples of green leaf and of the average tea made from it. The work could only be carried out satisfactorily by seeing gunnies of leaf of different tannin content through manufacture at the same time ; taking proper samples of green leaf and of finished tea. Without a factory on the Experimental Station it would be very difficult to arrange for such work.

For the present it is assumed that the quantity of tannin present in the fresh leaf does directly influence quality, although, as will be shown, it is not the only factor, and its influence can be masked by differences in manufacture.

Certain work on the variation of tannin in the leaf has been done. During 1921 the variation in the tannin content of the leaf plucked was followed in the Tocklai Laboratory through the whole season.

The two "leaves and a bud" plucked were taken to the laboratory and there sampled. The sample was separated by hand into four parts : (1) the buds, (2) the first leaves, (3) the second leaves, (4) the stalk, and the tannin estimated in each part.

The "high pruned" tea was pruned to 14″ from the ground, leaving 4″ one-year wood. The "low pruned" tea which the previous year was unpruned (skiffed) was pruned to 10″ from the ground, leaving 4″ of two-year wood.

The average percentages of tannin in the dried leaf are tabulated below :—

		Singlo Light leaf.	Burma Dark leaf.
Bud	from low pruned	24·8	23·6
	from high pruned	25·9	25·2
1st leaf	from low pruned	26·0	24·9
	from high pruned	26·5	25·8
2nd leaf	from low pruned	20·5	20·2
	from high pruned	22·3	25·7
Stalk	from low pruned	11·0	10·6
	from high pruned	11·8	11·3

Influence of Jat : It will be noticed that the light leaf consistently gives a higher average tannin content than the dark leaf although the differences are small.

When trials have been made in separately manufacturing leaf from light and dark varieties respectively, the tea from dark leafed bushes has obtained slightly lower valuations than tea from light leafed bushes.

Influence of Plucking : The variation in tannin in the various parts of the flush are also interesting.

The bud contains slightly less tannin than the first leaf, hence possibly a slight loss of quality in plucking immature leaf.

The first leaf, however, contains very distinctly more tannin that the second leaf. The tannin percentage falls off continuously as more leaves are taken, hence the falling off in quality with coarser plucking. The small percentage of tannin in the stalk is very noticable. This is the very young green soft stalk plucked with the bud and first two leaves. Old woody stalk would certainly contain still less tannin. Stalk, therefore, is rightly considered as lowering quality, although the reduction in price obtained for tea in which red stalk shows up, is out of all proportion to the lowering in quality of liquors due to the presence of the stalk.

Fine plucking, therefore, produces better average prices since the coarser 3rd and 4th leaves are excluded. As Mann points out, however, the quality of the first and second leaves is not improved by not plucking more leaves. The better average price from fine plucking is only due to making less of the coarser grades, with a corresponding decrease in crop.

With the same *fineness* of plucking, however, differences in the *closeness* of the plucking do make a difference to quality.

For example with bushes pruned to the same height, better quality is obtained on plucking two leaves and a bud after giving a short growth only, than on plucking two leaves and a bud from a longer shoot.

Mann gives as an example the following extreme case, from two plots treated similarly up till September (1905). The first was plucked after an interval of ten days, the second was plucked after an interval of twenty days, two leaves and a bud being taken in each case.

The ten day growth made tea giving ... 43·1% total solids.

Twenty „ „ „ „ „ ... 40·2% „

Such a difference would undoubtedly have produced a very great difference in selling price. General experience is agreed that within certain limits the closer the plucking the better is the quality of the tea produced; but if plucking is too close quality again suffers from the immaturity of the leaf. Mann points out that the ideal would be to pluck every day, taking ready leaf only.

That, of course, is quite impracticable. In practice probably weekly plucking does best, both for quality and yield ; ready leaf, only, being taken. The closeness of the plucking has to be regulated by the state of the bushes. So long as the bush remains vigorous the closer plucking gives both better quality and better yield ; but the bush soon suffers if the plucking is over-close. In this matter the Manager, guided by local and his own experience, has to exercise judgment.

Influence of Pruning: That a difference is produced by pruning is also clearly indicated. It is a matter of general experience that forced rapid growth from cut-back tea produces worse quality than that from ordinary top-pruned.

Any operation which appreciably reduces the leaf area stimulates the bush to more rapid growth. The bush takes food from the soil in solution. The crude food materials in solution are taken to the leaf where they are manufactured into substances which the plant can use, and the excess of water is given off by transpiration. There must always be a tendency to balance between the amount of water taken in by the roots and amount transpired by the leaves. When the balance is seriously disturbed, as by pruning, so that the remaining leaf area is insufficient for transpiration of the water taken in by the roots, then there is a period of rapid growth to make up the deficiency. Such stimulation of leaf growth is one of the objects of pruning. By heavy pruning a forced rush of growth is produced, and such growth is "watery" and gives poor teas.

Very heavy cleaning out will produce a similar effect, but in this case the balancing leaf area is soon made up, and loss of quality is noticed for a short time only.

After heavy pruning also the plucking is taken from the end of a long shoot instead of a short one, or in other words the shoot is plucked further from its point of origin.

In the case of the Tocklai plots in 1921 "the low pruned" was giving its new shoots from two-year wood left practically leafless, and the "high pruned" from one-year wood carrying

some leaves. Both were plucked at 27″ from the ground, so that the "low pruned" shoots were plucked 17″ from their point of origin, and the high pruned shoots at only 13″ from their point of origin.

In this case the variation due to either factor alone would not be expected to be very great. Even the combined effect of the two factors is small as may be seen from the table, but it is distinct enough to show up in every single instance. The average of all parts of the flush from dark and light leaf tea together being :—

Low pruned ... ... 20·3% tannin.
High „ ... ... 21·3% „

The difference in tannin content is probably sufficiently great to make an appreciable difference in the average price of the tea obtained from bushes of the two types of pruning. Previous to 1920, the plots had been treated identically.

Influence of Light : Hope showed that there is a direct connection between the amount of light falling on the leaf and the quality of the extract prepared from it. In this case the extracts were made under conditions approximating to the preparation of tea for drinking purposes. Several bushes were shaded by thatch such that half received natural sunshine, and the other half remained in heavy shade and never received direct sunlight. After a few days the shaded leaves became darker green, more shining, and the stalks were noticeably drawn out.

Analyses of the extracts gave :—

	Total solids.	Tannin.
1. In exposure	10·5	2·81
In shade	11·0	2·76
2. In exposure	8·0	1·96
In shade	9·0	1·70
3. In exposure	9·4	2·44
In shade	10·0	2·14
4. In exposure	10·8	2·36
In shade	11·0	2·11

While the total soluble matter is increased by the shading, the tannin is noticeably reduced.

Similar differences were obtained when bushes of the same type away from, and under Sau trees, were compared :—

	Total solids.	Tannin.
1. Away from Sau trees ...	10·1	1·75
Under Sau trees ...	11·1	1·44
2. Away from Sau trees ...	10·2	1·39
Under Sau trees ...	10·0	1·24
3. Away from Sau trees ...	10·4	2·28
Under Sau trees ...	10·0	2·08

Shade therefore reduces the pungency of tea. This fact is made use of in the production of green teas in Japan (where green teas are better liked if they show little pungency). Teas of very high value are produced by shading part of the garden with cloth.

The shading also improves the colour, a great point in a green tea. When black teas of good quality are desired it is clear that some care must be exercised in the use of shade trees. While benefitting the health of the bush when used in moderation over heavy shade will lead to loss of quality.

Apart from actual shade, lack of sunshine due to clouds was shown to have a similar effect on the tannin content of the leaf. In dull, overcast weather teas lacking in pungency are produced.

Effect of Manuring : Increases in crop are most easily produced by the use of nitrogenous manures. It is an observed fact, that other things being equal the more rapid growth induced by such manuring, produces a lowering of quality.

Bigger crops can however, be produced without increasing the rate of growth, by increasing the vigour of the bush so that it will support a larger number of shoots, and will allow closer plucking. It should be possible then to use manure to

increase crop without any loss in quality so long as it is accompanied by reasonable pruning and plucking. Hope analysed leaf from manured and check plots Heeleaka in 1910. He showed that while the very big flushes following the application of readily available manures like nitrates showed some diminution in total solids (and therefore presumably in quality), there was no appreciable difference following the application of equivalent quantities of slow acting oilcake. In these cases plucking and pruning were the same for manured and check plots.

By the mineral manures, phosphoric acid, and potash, it would appear that quality is rather increased than otherwise.

"Quality" districts always contain high proportions of these constituents in the soil. Good teas contain more potash and phosphoric acid than poor teas. In some few cases manuring with phosphates has led to noticeable improvement in liquors.

On the whole, then, we are of opinion that there is no fear of noticeable loss of quality from manuring, so long as the manures are well balanced, and pruning is adapted to produce a wide, healthy bush which allows close plucking. "Flat" plucking is also of assistance in producing the wide bush, since it allows no "running away" in the centre, and the outsides are relatively strengthened.

Variation with Season: The variation in tannin content with season can be traced from the curves facing page 57.

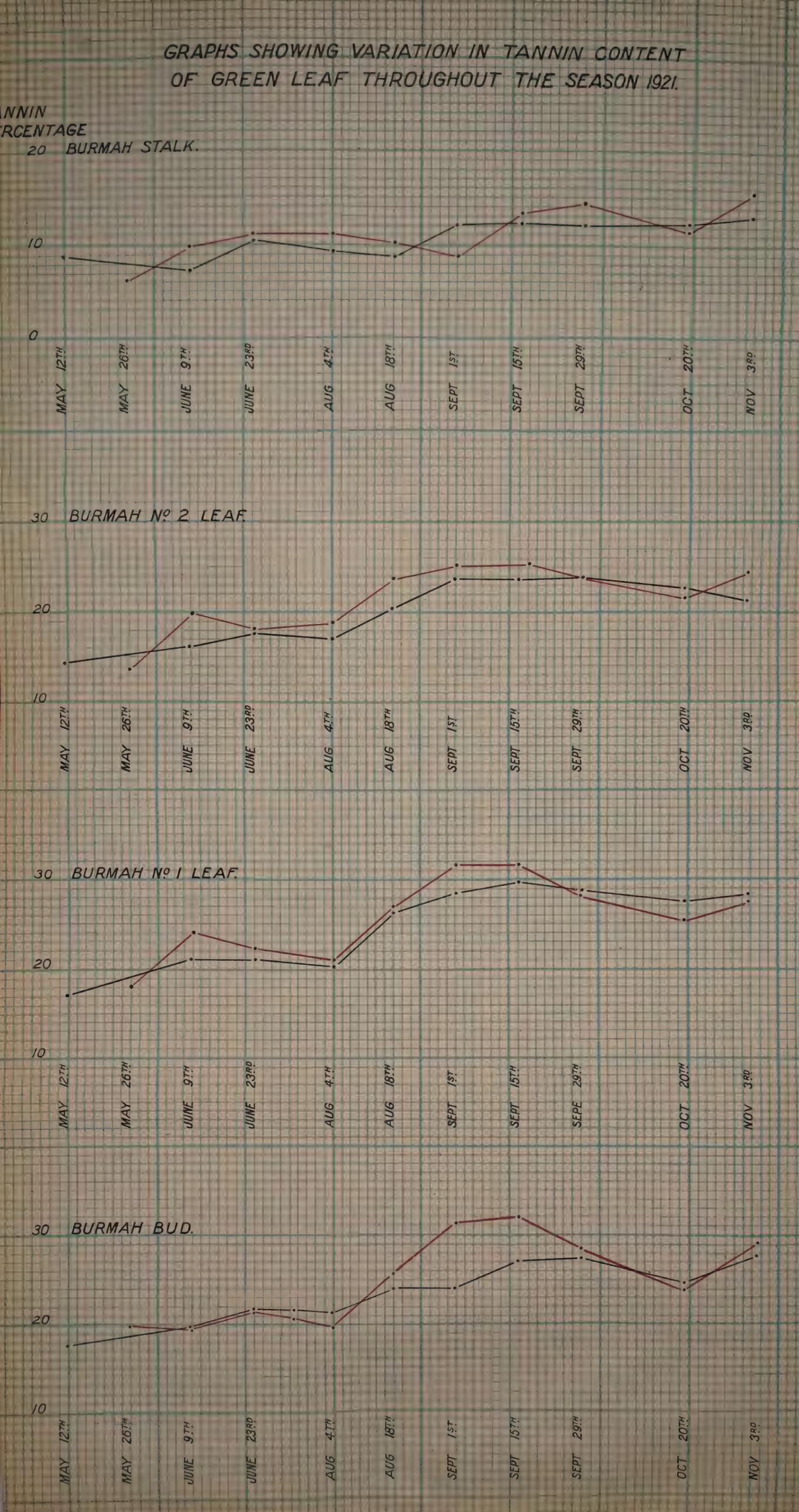
The curves are not exactly of the same form for both dark and light leaf varieties, but all the curves have the following features in common:—

(1) At the beginning of the season the tannin content is low, particularly in the very earliest pluckings. It is well known that the first flush does not make teas up to the average of the season.

(2) The tannin content is about its maximum during August and September and tends rather to fall off some time during October.

GRAPHS SHOWING VARIATION IN TANNIN CONTENT OF GREEN LEAF THROUGHOUT THE SEASON 1921.

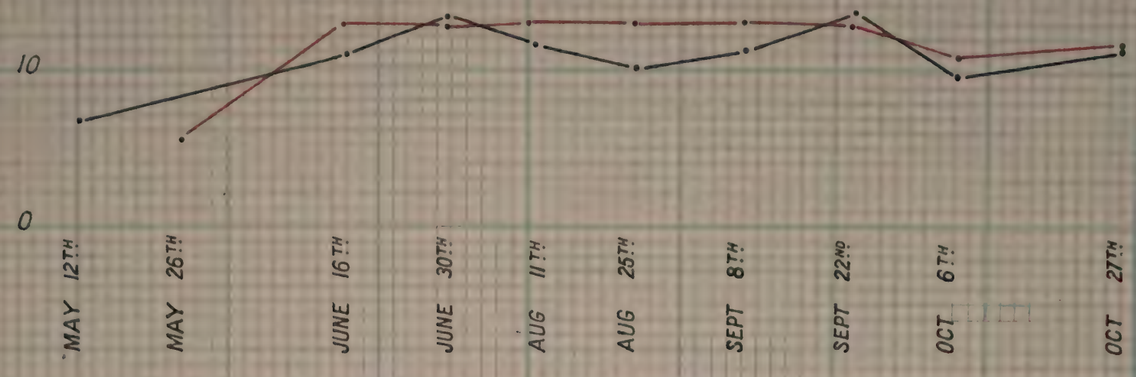
ANNIN
RCENTAGE



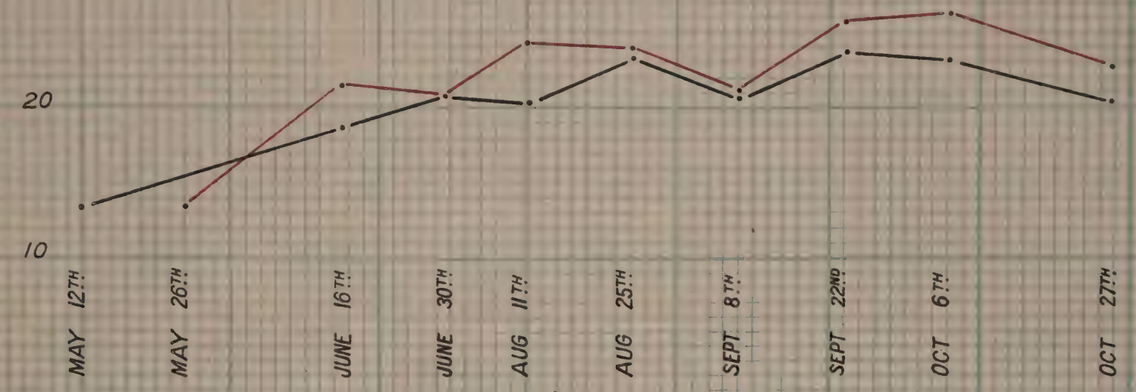
GRAPHS SHOWING VARIATION IN TANNIN CONTENT OF GREEN LEAF THROUGHOUT THE SEASON 1921.

TANNIN PERCENTAGE

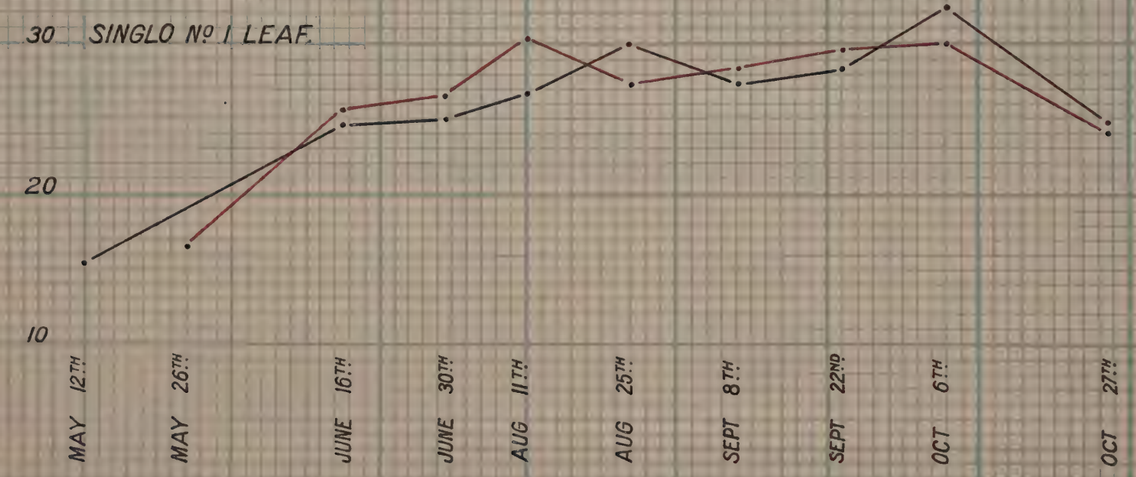
20 SINGLO STALK.



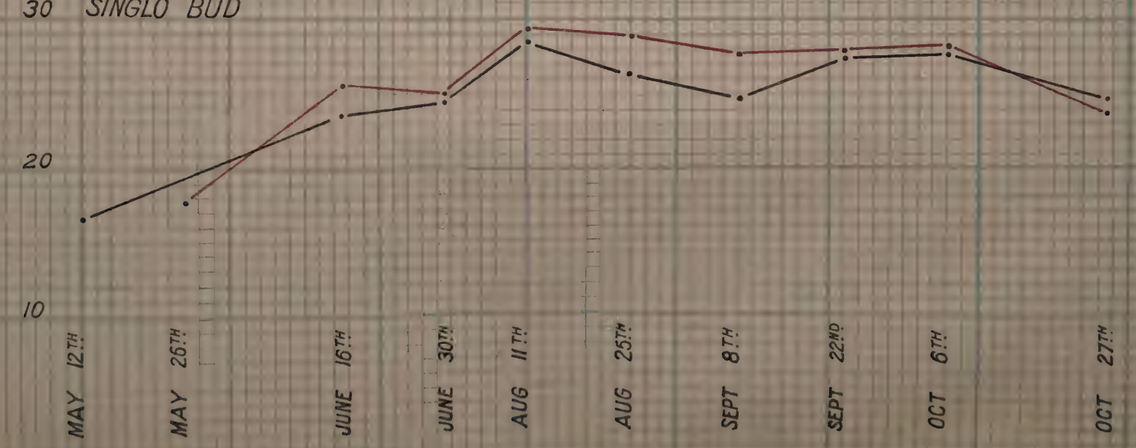
30 SINGLO Nº 2 LEAF.



30 SINGLO Nº 1 LEAF.



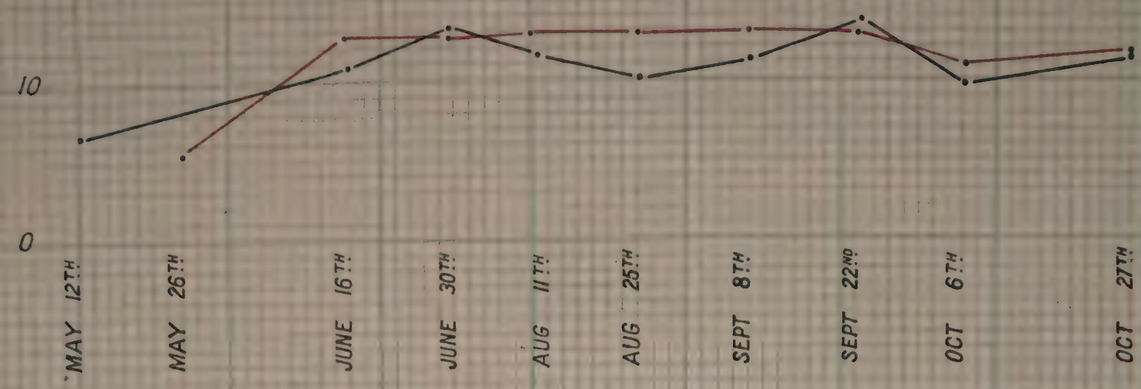
30 SINGLO BUD



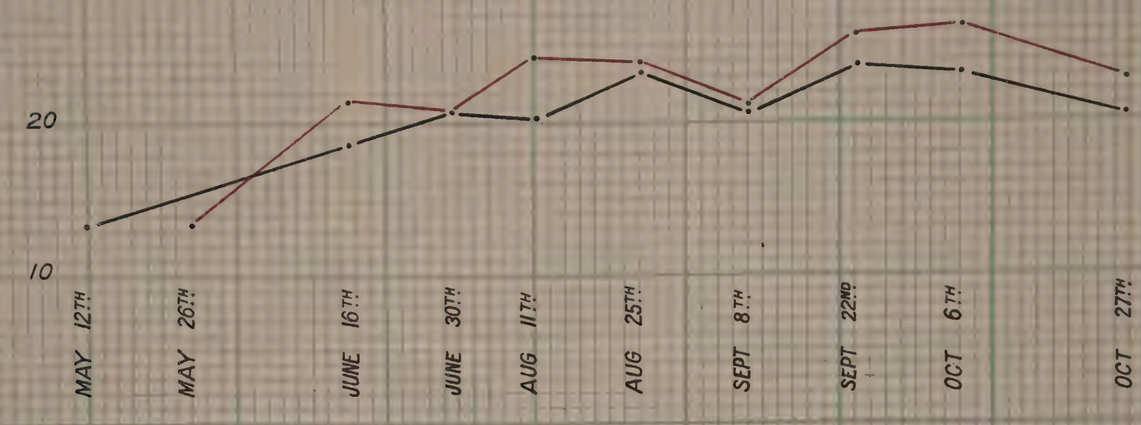
GRAPHS SHOWING VARIATION IN TANNIN CONTENT OF GREEN LEAF THROUGHOUT THE SEASON 1921.

TANNIN PERCENTAGE

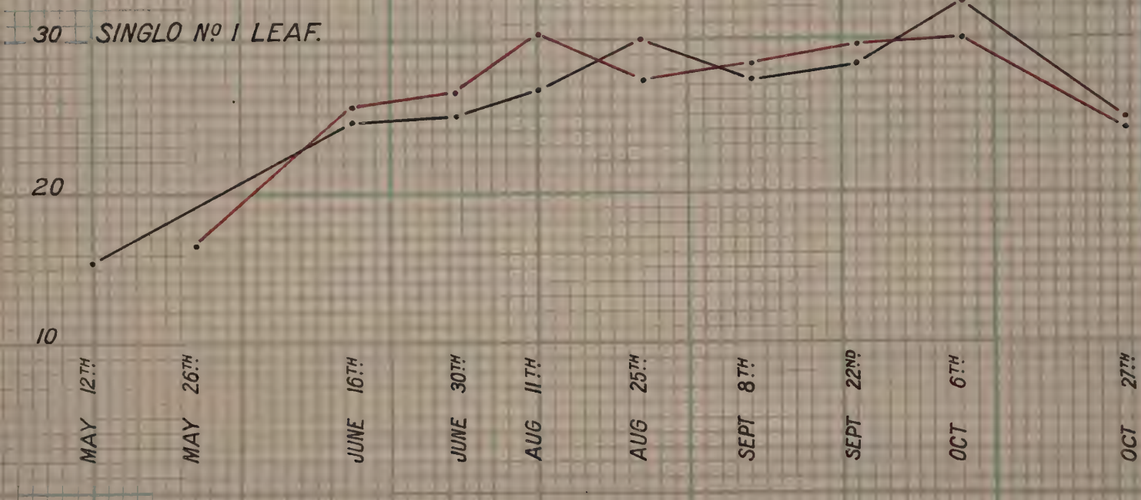
20 SINGLO STALK.



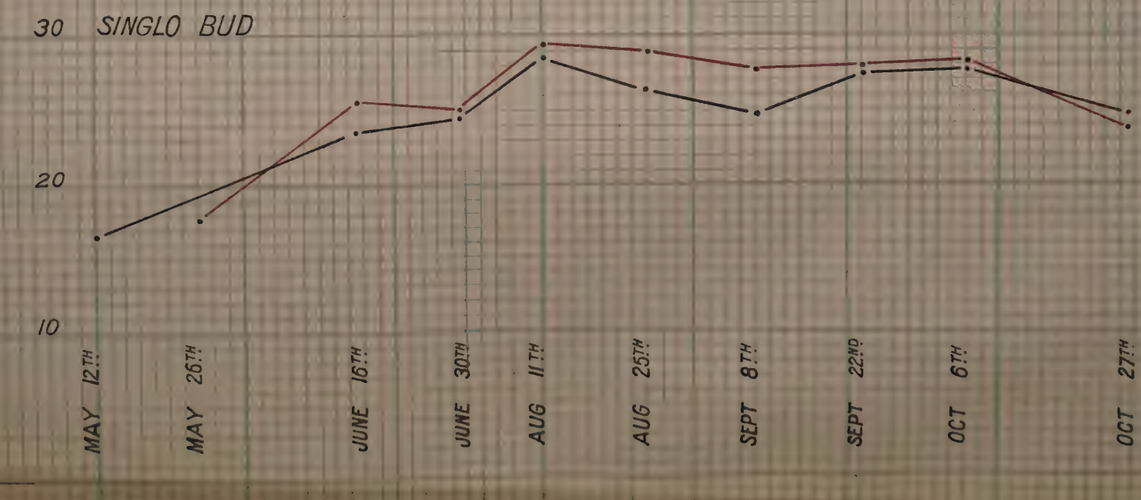
30 SINGLO Nº 2 LEAF.



30 SINGLO Nº 1 LEAF.



30 SINGLO BUD



In this case the figures obtained for tannin content do not correspond with what is known of variation of quality with season.

It would appear that if tannin is a great factor influencing quality, then quality should be highest during August and September. It is usually found, on the contrary, that there is a marked improvement in quality after the end of September.

Here some other factor must be so active as altogether to outweigh the influence of tannin. Factors likely to be active towards the end of the season are :—

(a) Increase in flavour, due to formation in greater quantity of the substances yielding aroma, which is very possibly related to lowering of the temperature during growth.

(b) Increase in quality, due to the improved atmospheric conditions for withering and fermenting as affecting both tannin and aroma.

Part III.

Having discussed the composition of the green leaf as plucked, it will be well to indicate how such knowledge as we at present possess may be used in the control of the successive stages of manufacture. In the manufacture of green tea the constituents of the green leaf are desired unchanged, the process being practically a drying process only with precautions against fermentive changes. In black tea we desire flavoury decomposition products, and a development of full aroma.

Withering : In the leaf-house two kinds of change are going on—one merely physical, and the other chemical. The physical change is the loss of water by evaporation, and is complete when the leaf has lost its turgidity and become sufficiently flaccid (or soft), to bend without breaking, so that it may be rolled without being unduly smashed up, and so that there will not be an undue loss of juice during the rolling.

The time required for this change to become complete depends upon the temperature, the dryness or moistness of the atmosphere,

and the presence or absence of wind. It is known that if this change is either too rapid or too slow, then although the leaf may be mechanically ready, it will not make good tea. Mann explained this as being due to the necessity of time for the increase in quantity of an oxidizing enzyme during withering. There appears to be more than that in it.

Tannins occur in the leaves of many plants, usually in combination with another substance (often a sugar). This compound is built up during the life of the leaf. After the death of the leaf the process is reversed, and under the influence of a hydrolysing enzyme the compound is decomposed by the water in the leaf. The freed tannin then combines with oxygen from the air under the influence of an oxidizing enzyme (oxidase) to form brown compounds.

With respect to tea this subject is still under investigation, but there appears at present every reason to believe that similar reactions occur in a plucked tea leaf.

It will have been noted that these reactions depend upon a loss of vitality of the leaf cells, and this loss of vitality is obtained by drying.

During withering, then, we require loss of vitality by drying, and then sufficient time for the hydrolyzing enzyme to act.

Should the rate of drying be too slow the leaf will not loose vitality sufficiently rapidly, on the other hand if drying is too rapid, the hydrolyzing enzyme will not have time to do its work.

As far as may be judged at present, in properly withered leaf the hydrolysis of the tannin compound should be nearly complete, while the oxidation to brown compounds should not have proceeded to any extent. That is, the leaf should still appear green, although on holding it up to the light a certain amount of browning will appear, particularly in the ribs, and the leaf must retain sufficient water to be still soft.

Under-withered tea will produce teas of great pungency, but with little colour or thickness of liquor. Over-withering produces

thick liquoring teas, of deep colour, but little pungency. If, however, withering is very much too slow or too rapid, teas having no good points may be obtained. In practice best results appear to be obtained when the leaf reaches the right stage in about 18 to 21 hours.

Under certain climatic conditions it is not always easy to arrange for this time.

In the early part of the season, particularly when there are hot dry winds, leaf may become brown and too dry in a night.

In such weather it is extremely difficut to make good tea, and the poor colour obtained is always noticeable. Conditions would certainly be improved by the use of side curtains for the leaf-houses, which would then contain the leaf in as still an atmosphere as possible. Rather thicker spreading, also, should then be used, although the teas will lose something in evenness.

In saturated atmospheres such as commonly occur in the Duars during the rains the difficulty is to get sufficient drying for loss of vitality in reasonable time.

In view of the above theory of withering, it appears that artificial drying should be applied at the *beginning* of the wither. When sufficient loss of vitality by drying has been obtained, the required reactions would then go on, although no further drying takes places. Previously it has been recommended that the drying should be at the end of the wither. This is still a matter for experiment in practice, and offers a very useful field for experiment in the factory. From theory it would be expected that when the atmosphere is nearly saturated, and it is necessary to use fan withering lofts, the following procedure should give best results. As soon as the leaf is placed in the loft, it should be subjected to the draught of hot air until dried to not quite the right physical condition : the fans should then be stopped so that little further drying takes place, and the leaf then left for the chemical reaction to proceed. This reaction may be judged to be complete when browning of the ribs of the leaf has occurred, while the rest of the leaf is still green. The drying may be regulated by experience so

that the total time of wither is about 18 hours ; although, since the temperatures will be high, less time may be found to be necessary. The action of the hydrolyzing enzyme is most rapid at 90°F.

Some precaution will be necessary, whether withering with or without fans, to obtain an even wither. If some leaves, or parts of leaves, are prevented from drying as rapidly as the bulk, then the undried parts will not have lost vitality sufficiently to colour at the same rate as the bulk during fermentation, and patchy teas will result. The balance between fermented and unfermented tannin may still be good so that liquors may possibly not suffer ; but such green patches always prejudice a buyer unfavourably, and in any case the rolling and fermentation of unevenly withered leaf are very much more difficult to control.

To obtain even withering several points need attention. Thin spreading will assist even withering. Leaf in the middle of a thick layer clearly cannot dry at the same rate as leaf on the outside.

The lower surface of a leaf dries more quickly than the upper surface. For both reasons the old practice of occasionally turning the leaf by hand is recommended. Bruising of the leaf by careless handling must be avoided.

Where fine teas are expected many managers prefer to wither on flat "chungs" made of split bamboo covered with Hessian cloth, rather than on galvanised iron wire-netting racks. Several reasons can be given for this preference.

Shoots that hang down through the wires, become rapidly over-dried and spoilt.

Then in a leaf-house, racks are usually spaced much closer together than are chungs. This gives less working space, and in consequence leaf is often not spread so evenly, and is more liable to become bruised and damaged in handling. Owing to the closer spacing, also, there is less free circulation of air, and leaf on the inside racks does not wither at the same rate as that on outside racks. The mugginess of the atmosphere in the centre of a rack-house is often noticeable on a windless day. The Hessian

cloth used for covering either chungs or racks must be kept clean as it may become a source of infection by undesirable micro-organisms.

Rolling: In the old days leaf after withering was rolled by hand, at that time great importance was attached to getting a "good twist" on the leaf, whereby the dried tea assumed a wiry appearance.

For a long time after rolling-machines had superseded hand rolling in nearly every factory, "good twist" was a point looked for in good teas, although now-a-days less importance is attached to it.

Now before the fashion was set, there could have been no reason why teas of any particular or peculiar appearance should be preferred. It must have been the case that teas showing "good twist" were generally noticed to be teas of good quality.

To start with, improperly withered teas will not take a twist, and as has been shown, this provides an excellent reason for believing that proper withering is essential for production of the highest quality. But there is more than that in it. Appearance was not the main object of manufacture, but the production of colour and flavour. By hand rolling, the production of tightly twisted rolls would be the most efficient method of damaging the maximum number of cells. A large number would be broken or killed while those still unbroken would have a large part of the cell sap squeezed out and so be reduced in vitality. We suggest, in fact, that the production of tightly twisted leaf gave the most even and complete reduction in vitality of the cells.

Under "Withering" we have shown that reduction in vitality is necessary for the changes desired in producing black tea leaf. Only when the leaf begins to die, are the coloured fermentation products of tannin produced under the influence of the enzymes present.

The young and delicate portions of the plucked shoots will lose their vitality more easily, and will ferment more rapidly than the older coarser portions.

Withered leaf is put into the rollers and rolled for a time, varying within wide limits (15 to 40 minutes). This first roll is usually carried out without any pressure from the weight cap, in order to avoid undue damage to those more delicate portions of the shoots. It is desirable, particularly, to retain the golden colour of the tip. The leaf is then put through a green leaf sorter. The fine leaf is then usually taken direct to the fermenting room, while the coarse leaf is put back into the roller. This second roll is given with more pressure, frequently with as much pressure as possible.

Often this leaf is again sifted and the coarse leaf rolled once more.

It will be seen that the rolling follows up the withering and effects a still further reduction in vitality, and the repeated rolls attempt to reduce the vitality of all parts evenly. Heavy rolling can so reduce vitality as largely to counteract insufficient or uneven withering, particularly when very fine teas are not expected.

The rolling, of course, does more than reduce vitality. Sap is squeezed out of the cells and rolled over the surface of the leaf. Leaf which went into the roller dry on the outside, comes out in a moist condition. After this point, micro-organisms can very materially affect the condition of the leaf. If undesirable bacteria (which do make their appearance at certain times of the year) are present in large numbers, undesirable products may be obtained. The leaf may become sour or acquire a musty or other undesirable smell.

At this point any desirable micro-organisms which may be present will begin to act.

The sap also is now exposed to the air, and the effect of this is to render more active the oxidizing enzymes which cause the formation of coloured compounds. Not only that but the greater the number of broken and damaged cells, the more easily extractable by boiling water will the soluble matter of the dried tea become.

The harder the rolling, therefore, the thicker and darker may the liquors be expected to be. The time of rolling, there-

fore, requires very careful consideration. For the second and succeeding rolls, when there is no tip or fine leaf to be damaged, it may be rolled for a very long time, but the pressure should not then be so great as to cause red juice to run out at the bottom of the roller, for this means the loss of liquor. Where long rolling cannot be given, then greater pressure must be used. The juice which then runs out, is commonly found to reduce quality if added to the leaf from which it came before that goes to the fermenting room. It produces flat teas. This red juice is already fully fermented when it leaves the rollers, and must also be very rich in oxidizing enzymes. Further fermentation not only spoils it, but to some extent the leaf to which it is added also.

This ready juice, therefore, should be mixed with leaf which has just left the fermenting room, and is being taken into the drier.

In the roller, leaf is of course fermenting, and the temperature should therefore be as nearly as possible the optimum for fermentation. During rolling temperature rises, particularly if much pressure is used. This is a great objection to the system by which the leaf is kept in the roller for nearly the whole of the fermentation time.

The system under which the leaf is rolled several times and removed and sifted between each roll is better from this point of view, since the leaf is allowed to cool. The finer leaf, also, which does need so much rolling, avoids being over-rolled.

On the other hand continuous rolling has advantages. Undue pressure may be avoided, and the rolling still be thorough. The leaf also is kept stirred so that no part becomes more oxidized than another, and it avoids the dangers of draughts and excess of air.

Fermentation: After withering and rolling are complete, the vitality of the leaf cells is very low indeed. The velocity of the reactions concerned in the making of black tea is the greater the lower the vitality of the leaf cells. The leaf therefore now changes its colour and other characteristics with great rapidity.

The colour produced is an index to the quality of the product. When a bright, coppery red, fine tea is made. When the colour becomes dull and brown, liquors will be soft, and although they may be thick and dark, they will not be bright.

It seems probable that the first colour is associated with the presence of "tannin red," while the latter is due largely to the presence of excessive quantities of "tannin brown" although undesirable micro-organisms may here play a part.

While we cannot yet completely control this stage of the manufacture, the following have been shown to be points of importance:—

1. The leaf must not be allowed to dry further. This is of particular importance during the hot dry days of the early season. When the hot dry air is assisted by a draught nearly black leaf is obtained in patches. This may be prevented by covering the fermenting leaf with a cloth. Mann protests against the use of such cloths. There is no doubt that they may easily become sources of infection by undesirable bacteria, but if kept scrupulously clean by boiling, there is no objection to their use. They are probably unnecessary in the rains, when the atmosphere is damp.

Even in the rains, however, draughts should be guarded against. Even if saturated with moisture, they still bring fresh oxygen, and excess of oxygen appears to be undesirable.

2. During the rains draughts may be prevented by hanging wet cloths round the walls of the fermenting room. This also has the effect of keeping the temperature down.

It is well established that the fermenting leaf must be kept at about 82°F. Any considerable rise means loss of quality, at temperatures greatly lower fermentation is too slow, but good results are obtained down to about 75°F. if the time of fermentation is increased.

At low atmospheric temperatures, leaf may be spread thicker so as to use the heat generated during fermentation to raise the temperature of the mass. At higher temperatures spreading must

be thinner, though there is no advantage in spreading thinner than about two inches.

3. The time of fermentation will depend upon the previous withering and rolling, and upon the temperature and the activity of the enzymes present. It averages approximately $3\frac{1}{2}$ to 4 hours, but in practice varies considerably.

The best test for complete fermentation is a practised nose. When the leaf has produced its maximum aroma and just begun to fall off slightly, it is ready to be fired. The colour of the fermenting leaf is also a useful help. It is not correct to wait until all the green patches have changed colour. The ideal is an even bright copper colour, but if through uneven withering or rolling some parts have escaped sufficient loss of vitality, then the bulk of the leaf is spoilt by the time the last green patch is gone.

A better balanced liquor is obtained by stopping fermentation whilst the greater part of the leaf is brightly red (even though patches are green), rather than by waiting till the whole is brown coloured.

4. An important point (which is not yet fully explained) is that an old fermenting floor produces better tea than a new one, and a cement floor gives better results than tiles or glass. This is particularly noticed on gardens making high quality teas, although it appears to make little difference in factories making common tea. Mann came to the conclusion that no micro-organisms other than harmful ones were present in fermenting tea, and therefore recommended that fermenting floors should be sterilized, and in many factories it has become the practice to regularly steam floors or to wash them with permanganate.

We do not recommend that such thorough cleaning should be altogether abolished, but that it should be used with discretion. So long as good teas are being made, then let well alone, and wash only with cold water and a broom or brush ; but as soon as unsatisfactory teas appear, particularly if "tainted," or of a bad colour, then sterilize by steaming or otherwise.

Firing: The drier raises the temperature of the leaf sufficiently to stop fermentation, and then removes water so as to leave the leaf too dry for further action when it has cooled.

Mann showed that a temperature of 150°F. was necessary to stop fermentation, and that it could be 180° F. without harm.

These are temperatures in the leaf which is kept cool by evaporation. The machine temperature must therefore be higher.

During the drying some tannin is decomposed, and also a large proportion of the essential oil is evaporated with the steam evolved. Both these losses are minimised by firing at a low temperature.

Some machines are arranged with a bye-pass so that hot air direct from the furnace can be turned on to the topt ray to stop fermentation. This allows a lower firing temperature for the remaining trays.

Essential oil is very volatile in steam, but very much less volatile in hot dry air. It is therefore very necessary that the leaf shall not be steamed, or aroma will be very seriously reduced. To obviate this a large supply of hot dry air must be forced through the leaf so as rapidly to dilute the steam, and the leaf must be spread thinly. Where flavour is the first consideration a machine temperature of 200°F. is recommended. For pungent teas temperature may be about 200° to 220°F. and for thick liquoring teas the temperature may be somewhat lower 180° to 200° F.

These are temperatures for the first firing. In subsequent machines it is of not so much importance that the temperature be kept down, although high firing is to be avoided until the leaf is nearly dry, otherwise a dry casing is obtained when the core of the leaf is still wet. This not only hinders drying, but renders leaf liable to be accepted as dry, which subsequently becomes soft as moisture from the core disseminates through the dry crust. For the second firing temperatures may well be kept at 220°F. These temperatures should be carefully controlled, and in order that control shall be efficient it is strongly recommended that

recording thermometers should be attached to each drier, or at least to those in which the first firing is done.

Leaf as it leaves the fermenting room occupies so much space that it is more convenient to complete the drying in two operations, the first machine drying the leaf to about 12 annas, the 12-anna-fired leaf (now reduced in volume) is then put through another machine.

This method appears to result in very little loss of quality. It is important, however, that the 12-anna leaf must not lie about in heaps while still hot. It should immediately be put into the second machine ; or where this is not possible, it should be spread out and cooled.

After the leaf has been completely fired it should be cooled rapidly and put into the air-tight bins so that it absorbs very little moisture from the atmosphere. Bins should be deep, as this will help to prevent absorption of water.

Sorting : This is a purely mechanical operation. The tea is sorted to suit market requirements at the time. Being purely a commercial problem it calls for no comment here.

Packing : Only one aspect of this question need be dealt with here, the moisture content at the time of packing.

Teas after sorting are usually kept in the factory till sufficient is collected to make a break, when the whole is bulked.

Unless the tea has been kept in good air-tight bins it will have absorbed moisture, and it will then generally be necessary to final fire or "gap" it before packing.

Final firing undoubtedly lowers quality somewhat. and should be avoided if possible by keeping tea in air-tight bins. However, if the tea is to exhibit keeping qualities, it should certainly not be packed with a moisture content above 9 %, and would be better about 7 %.

Work by Hope and Carpenter in Assam, and by Welter in Java led to practically the same conclusions. Best results are obtained by packing tea at about 6 to 7 % moisture content.

With moisture contents below 5% or much above 7% the tea does not keep. In either case tannin is lost, while with the higher moisture contents there is danger of the tea becoming mouldy. It is not possible to say whether tea should not be final fired without a definite determination of its water content.

Where it is considered necessary final firing should be carried out at low temperature (180°F.) in the shortest possible time.

C. O. P.—1,200—10-6-1922.